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The Influence of Livestock Feed Size on Feed Consumption by Starlings (Sturnus Vulgaris)

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THE INFLUENCE OF LIVESTOCK FEED SIZE ON FEED CONSUMPTION BY STARLINGS (*STURNUS VULGARIS*)

A Thesis

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Master of Science

by

Daniel J. Twedt

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THE INFLUENCE OF LIVESTOCK FEED SIZE ON FEED CONSUMPTION BY STARLINGS (*STURNUS VULGARIS*)

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I dedicate this paper to my wife, Shulee, for her love, patience and understanding.

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THE INFLUENCE OF LIVESTOCK FEED SIZE ON FEED CONSUMPTION BY STARLINGS (STURNUS VULGARIS)

Daniel J. Twedt June 1982 pages

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Ground meal and 4 sizes of pelleted feeds (3/16, 1/4, 3/8 and 1/2 inch diameters) were offered to captive Starlings (*Sturnus vulgaris*, Linnaeus) to determine the minimum feed size they were unable to consume in significant amounts. The ground meal, 3/8, and 1/2 inch diameter pellets substantially decreased feed consumption compared with 3/16 and 1/4 inch diameter pellets. Additionally, 1/2 inch pellets were consumed substantially less than ground meal or 3/8 inch pellets. Supplemental feed was required to prevent mortality among Starlings offered only 1/2 inch pellets.

Two pellet sizes, the 3/16 inch pellet which was readily consumed by Starlings and the 3/8 inch pellet which was less preferred by the birds, were selected for tests with free ranging Starlings. Field tests comparing consumption of these 2 pellet sizes were conduced in southcentral Kentucky during January and February 1982. Starlings consumed significantly ($P<0.01$) lesser amounts of 3/8 inch pellets than 3/16 inch pellets during this test.

It appears that feeding both ground meal and 3/8 inch diameter pelleted feeds to livestock is effective in reducing livestock feed losses to depredating Starlings, and feeding larger-sized feeds such as 1/2 inch diameter pellets may further reduce losses.

INTRODUCTION

Livestock producers have long considered the presence of blackbirds and Starlings at livestock feeding areas (feedlots) to be a major economic problem. Indeed, in an opinion survey (Hobson and Geuder 1976), 2,051 Tennessee farmers estimated annual losses of livestock feed to birds at $4.2 million. A subsequent opinion survey (Glahn et al. 1980) indicated 59% of 301 Tennessee farmers questioned considered blackbirds and Starlings a moderate to serious problem in their feedlots. In both surveys Tennessee farmers believed that monetary losses due to direct feed consumption and/or spoilage of feed by birds were greater than losses due to disease transmission by birds.

Results of studies conducted by livestock specialists at Western Kentucky University (Stone 1980, 1980a) indicated little or no adverse effect on feed acceptance, rate of gain, or feed efficiency of calves and swine when fed livestock feed contaminated with Starling fecal matter. Conversely, Gough and Beyer (1982) have demonstrated that Starlings can act as vectors of transmissible gastroenteritis (TGE) among swine. Economic losses resulting from birds acting as disease vectors have not been quantified.

Actual feed losses to birds at livestock or poultry feeding areas have been reported in the United States, Great Britain and Australia, with depredations probably taking place worldwide. Estimates of the amount and monetary value of feed loss vary. Stanhope (1966) estimated feed losses to birds at a poultry farm in Australia in the amount of 11 tons with a monetary value of \$550 per annum. In Great Britain an estimated 9% of the barley offered to cattle, or nearly 12 tons valued at \$2,000, was lost to Starlings (Feare and Wadsworth 1981). Wright (1973) estimated 1,000 tons of pelleted duck food valued at \$66,000 was lost to Starlings. An estimated 6% to 12% of calf feed (2 tons/yr) was consumed by Starlings during each of 3 consecutive winters (Feare and Swannack 1978).

Losses in the United States have been estimated at \$84/1000 Starlings and \$2/1000 Red-winged Blackbirds (Agelaius phoeniceus, Linnaeus) in a Colorado feedlot (Besser et al. 1968). White (1980) estimated that Starlings consumed a maximum of 2.1% of the livestock feed fed within the foraging area of a large winter blackbird-Starling roost near Milan, Tennessee. Glahn et al. (1980) estimated losses to birds at Tennessee feedlots during the winter of 1979-80 at less than \$700,000.

In Tennessee Glahn and Otis (1982) have found an association between bird damage at livestock feedlots and feedlot proximity to winter roosting concentrations of blackbirds and Starlings. An 'average' winter roost in Kentucky and Tennessee consists of 1.0 million birds of which 38% are Grackles (Quiscalus quiscula, Linnaeus), 23% Starlings, 39% Red-winged Blackbirds and Brown-headed Cowbirds (Molothrus ater, Boddaert), with lesser numbers of Rusty Blackbirds (Euphagus carolinus, Muller) and Robins (Turdus migratorius, Linnaeus) (Royall 1977, Heisterberg 1978, Stickley 1980).

Although Grackles are the most numerous species in these winter roosts, Starlings are the species of primary concern in feedlot depredations. White (1980) found that Starlings used feedlots more commonly than did Grackles or Red-winged Blackbirds, with Starlings representing 59% of the total feedlot bird population and 75% of the populations found in hoglots.

Dolbeer et al. (1978) reported 69% of birds in hoglots were Starlings. Glahn et al. (1978) found 100% of the birds actually in feed bunkers at dairies were Starlings. Similar findings on bird species using feed troughs, although less than 100%, were noted by Besser et al. (1968) and White (1980).

Starlings are not only the most prevalent bird in livestock feedlots and the dominant species in feed troughs but they also selectively choose expensive, high-quality feeds from a mixed livestock ration. Although Feare and Swannack (1978) found Starlings prefer barley over a pelleted concentrate, Besser et al. (1968), Crabb (1978) and Glahn and Otis (1981) found Starlings preferred high quality pelleted livestock feeds. Due to the amount of time spent in feedlots and their selective feeding habits, Starlings cause 40 times the economic loss of Red-winged Blackbirds. From these data it is clear that preventing Starlings from consuming pelleted feeds would be extremely beneficial in resolving the problem of feed losses to birds at livestock feedlots.

There are 2 basic approaches to preventing Starlings from consuming pelleted feeds; I have termed them "active" control and "passive" control. Active control involves the use of chemical or mechanical means of killing or frightening birds. Chemicals such as Starlicide^R, Avitrol^R and Alpha-chloralose have been used to control birds at feedlots (Besser et al. 1967, Feare et al. 1981, Glahn 1982). Mechanical devices such as traps, shooting, effigies or sound (Bogatich 1967, Inglis 1980, Slater 1980) have also been used for bird control.

There are drawbacks to the use of active controls. A potential poisoning hazard to humans, livestock, and nontarget wildlife exists whenever toxic chemicals are used. Some active controls are ineffective, particularly when used improperly. Some are costly in terms of dollars spent on chemicals while others are costly in terms of labor required for their operation. Active controls are generally not long-term solutions to the problem of depredating birds. Rapid reinfestation of feedlots by birds after active controls are terminated usually occurs.

Passive controls are management practices that discourage or prevent birds from feeding at feedlots. Passive controls are therefore long-term solutions to bird depredations and after the initial investment they are generally inexpensive to maintain. There are 3 basic management practices that will lessen Starling depredations at livestock feedlots; physical separation of feed from birds, offering livestock feeds that are unpalatable or unusuable to Starlings, or offering a feed size that Starlings cannot ingest (Twedt and Glahn 1982).

Various feed sizes, generally obtained by 'pelleting', have been used in feedling livestock. Pelleting is a process of particle size upgrading by compaction and extrusion whereby loose bulky material, ranging from a powder to a granular form, is compressed and formed into a pellet of increased bulk density. Pelleted feeds have resulted in significantly better animal performance for chickens (Nelson et al. 1980), swine (Braude et al. 1960, Seerley et al. 1962, Jenson and Becker 1965, Braude and Rowell 1966), cattle (Weir et al. 1959, McCroskey et al. 1961) and sheep (Esplin et al. 1957).

Church and Fox (1959) found no significant differences in the response of lambs fed 1/4, 3/8 or 1/2-in diameter pellets. Similarly, Garrett et al. (1961) found no consistent patterns in the response of steers to ground meal, 1/4 or 5/8-in diameter pellets or 4 in wafers. Brown et al. (1952), however, found milk producing cattle preferred 1/4-in pellets over 1/2-in pellets.

Glahn and Otis (1981) found Starlings consumed 3/16-in diameter pelleted livestock feeds at a rate 8 times greater than of ground meal consumption.

Spencer (1961) found that Starlings consumed 5/32-in diameter pellets to a greater extent than 1/16 or 1/4-in diameter pellets or a 3/4 x 1 1/14 x 2-in cube. In this study I attempted to determine the minimum pellet size which Starlings are unable to consume in significant amounts yet which is still acceptable in size to livestock and livestuck producers.

METHODS

Three series of cage tests, in which captive Starlings were offered different sizes of livestock feeds, were conducted intermittently from March 1980 through March 1982. A field test comparing consumption of 2 pellet sizes by free ranging Starlings was conducted from December 1981 through February 1982.

Livestock Feed Sizes

Standard livestock feed pellet sizes {5/32 (4.0 mm), 11/64 (4.4 mm) and 3/16-in (4.8 mm) diameter}[1] were available in several formulations from local feed distributors. Initial attempts at securing other pellet sizes were largely unsuccessful with only 3 sizes larger than 3/16-in being located. These were 3/4-in (17.0 mm) square cubes, 1/2-in (12.7 mm) diameter pellets, and 1/4-in (6.4 mm) diameter pellets. The 3/4 and 1/4-in feeds were available only in a cattle roughage formulation containing high fiber content and were excluded from the test for fear of rejection by Starlings (Knittle et al. 1980). Subsequent attempts to locate a commercial livestock feed pellet between 1/2-in and 3/16-in diameter were unsuccessful. The California Pellet Mill Co., Crawford, Indiana, however, agreed to produce small quantities of experimental pellets 1/4-in and 3/8-in (9.5 mm) diameter from commercially available livestock feeds.

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[1]Because they are produced by dies of known English system dimension, pellet diameters will continue to be expressed in fraction of inches while other data will be presented in metric measurements.

All feeds obtained were made from commercial 'complete hog rations' intended as a complete ration for swine. Ground meal and 3/16-in diameter pellets of similar formulations were obtained from Pan-American Mills, Bowling Green, Kentucky, with not less than 15% and 16% crude protein, respectively. The 1/2-in pellets with no less than 15% crude protein, marketed as a feed for brood sows, were obtained from Keco Milling Co., McKenzie, Tennessee. The stock feed from which the 1/4-in and 3/8-in diameter experimental pellets were produced was supplied by United Feeds, Inc., Sheridan, Indiana. This feed, a complete hog weaner with a crude protein content not less than 17%, was pelleted by the California Pellet Mill Co.

The ground meal consisted of small, irregularly shaped granules, generally less than 1/8-in (2.0 mm) for each dimension; however, larger particles such as cracked or whole kernel corn were often noted. Physical characteristics for the cylindrical pellets are presented in Table 1. Pellets were sifted prior to use to remove dust and small pieces. The 1/2-in pellets were screened with a 6.5 mm^2 mesh hardware cloth while other pelleted feeds were grossly hand sifted.

Cage Tests

Series I: No-choice preference tests; meal, 3/16 and 1/2-in pellets.

The initial series of cage tests conducted from 19 March 1980 to 10 April 1980 compared daily consumption by captive Starlings of 3 feed sizes: ground meal, 3/16-in and 1/2-in diameter pellets. This series consisted of 4, 3-day tests utilizing 5 Starlings per cage and 1, 3-day test utilizing 20 Starlings per cage. The increase in the number of birds per cage was to determine if an increased number of pecks by Starlings would cause pellet disintegration and allow greater consumption. Six cages were used for each test period. Starlings in groups of 5 (3 males, 2 females) were placed in

TABLE 1. Physical characteristics of livestock feed pellets.

	3/16"	1/4"	3/8"	1/2"
<u>Length (mm)</u>				
N	100	114	132	45
$\bar{X} \pm SE$	8.33 ± 0.36	15.90 ± 0.27	25.29 ± 0.37	18.02 ± 0.75
Range	2-23	[illegible]-20	12-33	6-27
<u>Weight (g)</u>				
Average weight	0.18	0.56	1.97	2.22

circular cages, 53 cm in diameter and 46 cm high, each equipped with a perch across the diameter of the cage; cage sides were constructed of 2.5 x 5.0 cm welded wire, and the tops and bottoms were made from 2.5 cm^2 mesh poultry screening. These cages were located in an outdoor alcove with a roof and 2 walls that afforded protection from inclement weather. Water was provided <u>ad libitum</u> by means of Porkmaster® #79 creep waterers (Nelston Products Co., Sioux Rapids, Iowa 50585) inserted through the side of each cage. The exposed water in each poultry waterer was covered with 6.5 mm^2 mesh hardware cloth to prevent the deposition of pellets into the water, thereby causing degradation of the pellets and rendering them unrecoverable. Feeds were offered in 10 x 10 x 10 cm plastic weighback feeders similar to those used by Brunton and Schafer (1981).

Groups of 20 Starlings were placed in 6 outdoor enclosures, 3 x 3 x 1.5 m high, equipped with 2, 1 m long perches suspended approximately 0.5 m below the roof panel. These enclosures were erected over 4 mil-thick black plastic by wiring together 3 x 1.5 m panels made from 5 x 5 cm creosote-treated lumber frames onto which either welded wire or poultry screen had been attached. Entry was gained through a 1 x 1.5 m doorway in 1 panel per enclosure. Water was provided <u>ad libitum</u> in circular, one gallon plastic poultry waterers within each enclosure. Feeds were offered in 100 x 20 x 20 cm-high wooden V-troughs.

Prior to all tests naive Starlings (birds not previously exposed to test feeds) were maintained on Purina Layena® crumbles, a poultry feed size between the meal and the 3/16-in pellets. In each test the 6 cages or enclosures were divided into 2 blocks. Each cage or enclosure within a block received a different feed size daily in a paired (3 x 3) latin square, switch-back design (Federer 1955). This particular design was used to account for residual effects of the different feed sizes offered among days (i.e. to account for exaggerated consumption of an edible feed size after exposure to an inedible feed size).

Each group of 5 Starlings received 200 g of feed daily for an 8 h period (0800-1600), and each group of 20 Starlings received 1000 g for the same time period. Spilled feed was recovered at the end of the day and combined with the feed remaining in the feeder. This feed was weighed to the nearest 0.5 g. Data were reduced to grams consumed/bird/8 h day prior to analyses.

Excessive mortality associated with the 1/2 in pellets in the initial test indicated the need for supplemental feeding to prevent bird mortality. Thereafter, at the end of each 8 h day, one half of an apple (ca. 50 g) was placed in each cage. Due to this excessive mortality, the data from Test A with 5 Starlings per cage and Test E with 20 Starlings per cage were each analyzed separately. Data from the other 3 tests (B,C and D) were subjected to a combined analysis.

Series II: No-choice preference tests; 3/16, 1/4 and 3/8-in pellets.

The next series of cage tests compared consumption by Starlings of 1/4-in and 3/8-in diameter experimental pellets and the 3/16-in diameter standard commercial pellets. Test cages, procedures, and locations were as described above for the tests with 5 Starlings per cage, except that the Porkmaster® waterers were replaced by Oasis Hamster Bottle waterers (Oasis Pet Products, Div. Atco Mfg. Co. Inc., 461 Walnut Street, Napa, California 94558) on 3 of the 6 cages. But based on the results of the previous tests the experimental design was modified so that the paired data sets were dropped from the basic 3 x 3 latin square. Data from these 3 x 3 latin squares were combined prior to analysis to gain increased degrees of freedom. Three 3-day tests (Tests A,B, and C) were conducted between 31 March 1981 to 22 April 1981. Five Starlings per cage were used in

Test A and 3 per cage were used in Tests B and C. The same individual Starlings were used in both Tests B and C. Eight additional cage tests (Tests D-K) comparing 1/4, 3/8 and 3/16-in diameter pellets were conducted from 10 November 1981 through 17 January 1982 (five 3-day tests with 1 Starling per cage and three 3-day tests with 5 Starlings per cage).

Series III: 2-choice preference tests.

A series of 24, 1-day, 2-choice preference tests, comparing consumption of 3/8 in diameter pellets with consumption of ground meal or 3/16 in pellets by captive naive Starlings, were conducted from 17 February 1982 through 30 March 1982. In 13 of the tests 1 Starling per cage was tested and in the remaining 11, 5 per cage were used. These birds were offered a choice of 2 feeds in separate weighback feeders for 8 hours. Differences in daily consumption between feed types were compared by Students t-test analysis.

Field Test

Two livestock feed pellet sizes were selected for use in field tests. One was the standard commercial 3/16-in diameter feed pellet, which Starlings were known to consume in significant amounts (Glahn and Otis 1980). The other was the 3/8-in diameter experimental pellet, which appeared to be resistant to Starling consumption.

Seven livestock feeding areas were selected for use as test sites in southcentral Kentucky (Fig. 1). These feeding area-test sites were located in 4 different geographic areas with no more than 2 test sites within any one area. Test sites either had Starlings present when selected or had had Starlings feeding at the feedlot in previous years. Two sites were abandoned due to inadequate Starling numbers but 2 additional sites were selected prior to the initial test period. All test sites were within foraging distance of historic winter blackbird/Starling roosts (Shadowen 1972, Stickley 1980, Mason 1981), and I attempted to locate those roosts that were active during this study.

Figure 1. The area where field tests on livestock feed pellet consumption by Starlings were conducted in 1982.

N
WARREN
2 1
4
3
BARREN
LOGAN
6 5
7
KENTUCKY

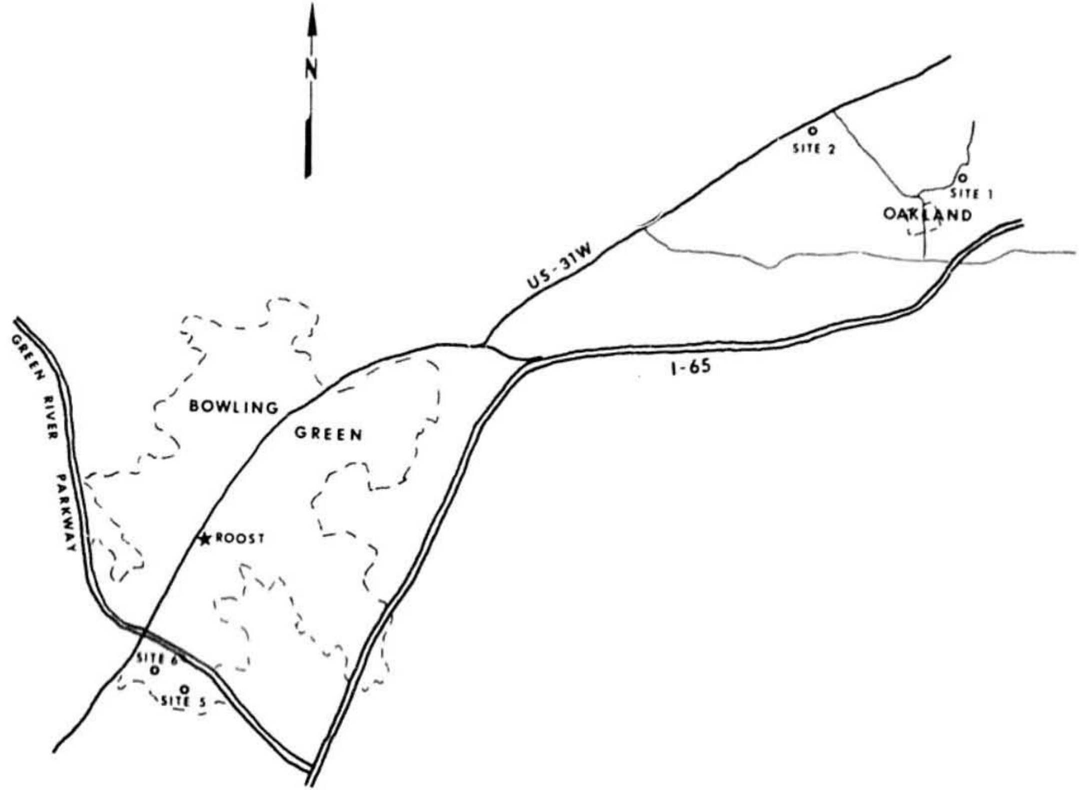
Two dairy heifer operations, where corn silage with some supplemental grain products was fed, were used as test sites (Sites 1 and 2) in north Warren County, near Oakland, Kentucky (Fig. 2). Silage was offered twice daily with some silage nearly always within the feed bunkers. Both sites had electric water tank heaters that allowed Starlings access to free water even at subfreezing temperatures.

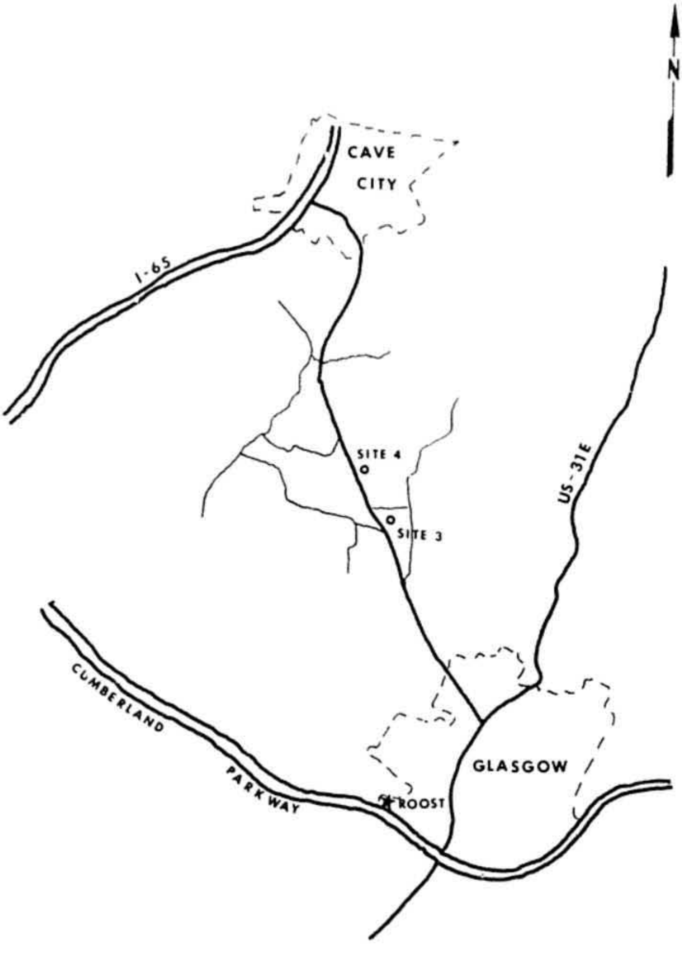
Two test sites were located in Barren County between Cave City and Glasgow (Fig. 3). One site (Site 3) was a dairy heifer operation which offered hay with small amounts of grain products (ground and whole). These products were rapidly consumed by cattle, thereby minimizing Starling access to these grains. A heated stock watering tank provided water. A ground meal, hog developer (similar to the test pellets), fed via flip-top self feeders, was fed at the other site (Site 4) and was continually available to the hogs. A large pond located within the hog lot provided water.

The 2 test sites located in south Warren County were both within the boundaries of the Western Kentucky University (WKU) Farm.(Fig. 2). Site 5 was a hog lot where a ground meal hog developer was provided via flip-top feeders, and automatic self waterers provided little or no access to water by birds. The other site (Site 6) was a dairy and beef cattle operation, where corn silage top dressed with ground grain products and hay were fed. No water was provided at this feed site; however, cattle and birds had access to a pond a short distance away.

The single Logan County site (Site 7), located 1 km south of Auburn, Kentucky, was a beef cattle operation in which adult cattle were fed only hay and pasture. The calves, however, had access to an outdoor creep feeder containing ground grains. This feeder was a roofed open-trough model to which Starlings had continual access. Water was provided by a pond approximately 200 m from the feeder.

Figure 2. The locations of Warren County livestock feeding areas used as test sites in field studies.


N
SITE 2
SITE 1
OAKLAND
US-31W
I-65
BOWLING
GREEN
GREEN RIVER PARKWAY
ROOST
SITE 6
SITE 5


N
CAVE
CITY
I-65
SITE 4
SITE 3
US-31E
CUMBERLAND
PARKWAY
GLASGOW
ROOST

One experimental wooden V-trough (0.4 x 2.5 x 0.6 m high) was placed at each test site. These troughs were located as close as possible to actual livestock feed troughs while still being in areas not accessible to livestock. The greatest distance between livestock and experimental troughs was less than 25 m.

Two troughs, instead of the usual 1, were placed within 10 m of each other at the Logan County site on 19 December 1981. Here each trough contained a known amount of a different size test pellet, and both troughs were exposed simultaneously. Daily, 24-h, consumption of both pellet sizes by Starlings at the site was determined by weighback calculations. Feed sizes were alternated daily between feed troughs to minimize preference due to location. Data from this 2-choice preference test with free ranging Starlings were analyzed with t-test statistics to determine differences in consumption between pellet sizes.

Purina Game Bird Maintenance Chow® crumbles (Ralston Purina Co., St. Louis, Missouri) were placed in troughs prior to the start of the initial test period at all sites, other than Logan County, to attract Starlings to the experimental feed troughs and establish consumption patterns within each trough. After a minimum of 2 days of preconditioning with crumbles, 1 of the 2 test pellet sizes was randomly selected for each test site. A known weight of the selected pellet size was placed in its respective experimental trough, generally between 0700 and 1000 h. Pellets remaining after 24 h of exposure were removed and weighed to determine consumption. A similar known weight of the second test pellet size was then placed in the trough, and consumption was again determined after 24 h via weighback of the remaining feed. During the next 24-h period crumbles were again exposed in the experimental troughs and, following this, the 2-day test sequence was repeated with test pellet sizes again randomized for each feeding location. The amount of pelleted feed exposed within each geographic area was increased or decreased based on previous consumption. This method of exposure, intended to minimize wasted pelleted feeds, was beneficial since only a finite amount of 3/8-in diameter pellets was available and only previously unexposed pellets were exposed during the tests.

The above procedure yielded a minimum of 7 sequence replications at all sites with a maximum of 11 sequence replications at 2 sites. Data obtained were analyzed by means of Statistical Analysis Service (SAS Institute, Cary, N.C.), General Linear Models (GLM) Type IV, analysis of variance. This program uses a weighted least squares analysis of variance intended for use with incompletely blocked data.

Variations of the test regime were necessitated due to inclement weather. During periods of rain, crumbles were left in troughs for 2 consecutive days prior to exposure of test pellets. Test pellets were not exposed during periods of rain. Rain or predicted rain occasionally required early termination of a 24-h test period. Snow, however, did not effect scheduled feed exposure. Moisture laden exposed feeds, either by rain or snow, were dried with fan circulated air for a minimum of 48 h or until dry to the touch prior to weighback.

Estimates of the number of Starlings at the feeding locations were made by daily flush-counts while changing the feeds in the experimental troughs at the north Warren County and Barren County sites. At the South Warren County sites a predetermined transect route circa 4 km in length was driven within the boundaries of the Western Kentucky University Farm, and the total Starlings counted was considered the number of birds foraging at these sites. No estimate of Starling numbers was made at the Logan County site.

Time-lapse cameras were positioned at 4 of the test sites to photographically record birds feeding at the experimental troughs. Three models of cameras were used: Minolta Autopak-806 Super-8 with Telonics intervalometer, Kodak Analyst Super-8 with built-in intervalometer, and Canon AZ814 Super-8 with Telonics intervalometer. These cameras, loaded with Kodachrome 40 ASA color film, were set to shoot 1 frame every 10 seconds with a maximum capacity of 3600 frames. Developed films were projected onto a viewing screen by means of an L&W International MKV Super-8 Analytical film projector. From these film records the total number of Starlings actually within the trough and the total number of Starlings sitting on the edge of the trough were separately enumerated and recorded for each frame. Total film-bird numbers for all frames and the total film-bird numbers from every 6th frame (i.e. 1 frame/minute) for each film-day were compared with pellet consumption on that day. These data allowed the calculation of the estimated consumption per film-bird-minute and per film-bird-frame. Film-bird-minutes are defined as the number of Starlings counted on every 6th frame for 'X' number of frames. Film-bird-frames are the number of Starlings counted on every frame for 'X' frames. Data were collected almost entirely on 3/8-in pellets. Similar data have previously been collected on 3/16-in pellets and ground meal (Glahn and Otis 1981, Glahn Unpublished).

In conjunction with these camera observations, 140 Starlings were color marked with individual identifying tags at the WKU farm. Back tags (Furrer 1979) made from Stamoid PE® (Stamm Ltd., CH-8193 Eglisau 2H Switzerland) in both yellow and white were placed on 99 Starlings between 18 January 1982 and 4 February 1982. Wing tags (Curtis 1981) made from Saflag® (The Safety Flag Co. of America, P.O. Box 1005, Pawtucket, RI 02862) in both yellow and white were placed on 41 Starlings between 20 January 1982 and 4 February 1982. Individually identifying letter-number combinations were applied to tags with Allflex® Tag Pen (Allflex Co., New Zealand). Starlings were able to be individually identified on the time-lapse film by means of these coded tags. The total number of frames and therefore the total length of time an individual Starling remained at the feed trough during a visit was determined using these data.

Climatological data were obtained from the Western Kentucky University weather station, Bowling Green, Kentucky. These data were compared with feed consumption and the number of Starlings observed at the feeding locations to determine any weather-related associations.

RESULTS AND DISCUSSION

Cage Tests

Series I: No-choice preference tests; meal, 3/16 and 1/2 in pellets.

Twenty percent mortality was associated with the feeding of 1/2 in pellets during Test A. Consumption and mortality data from this test are presented in Table 2. Due to excessive mortality in this test I analyzed this test data independently. Results indicated a highly significant ($P<0.01$) difference among feed sizes while no significant ($P>0.05$) differences were detected for any other effects.

Consumption data from Tests B, C, and D with 5 birds per cage (Table 3) were assimilated into a combined analysis of variance. This combined analysis yielded highly significant ($P<0.01$) differences among days and among feed sizes (direct treatment effects). Significant ($P<0.05$) differences were found among cages within blocks and possibly attributed to the days x blocks interaction. No significant ($P>0.05$) differences were detected among blocks or among the residual (effect of feed consumption 1 day on feed consumption the next) treatment effects.

These data indicate the different feed sizes had a significant effect on consumption. The amount of a feed consumed on 1 day, however, did not affect the consumption of a different feed the following day. The birds appeared to adjust to the feeding schedule and increased their feed consumption over the 3 days of exposure. The differences among cages may have been due to weight or age differences; but as these parameters

TABLE 2. Consumption (grams consumed/bird/8-h day) of ground meal (a), 3/16-in diameter pellets (b), and 1/2-in diameter pellets (c) by groups of 5 Starlings in cage tests at Bowling Green, KY.

Series I		Block I			Block II			
Test	Date	Cage 1	Cage 2	Cage 3	Cage 4	Cage 5	Cage 6	Total
	19 March 1980	a 25.2	b 28.6	c 5.3**	a 25.2	b 29.8	c 6.8*	120.9
	20 March 1980	b 30.4	c 10.7*	a 18.0	c 4.5	a 21.0	b 28.3*	110.9
	21 March 1980	c 7.8*	a 17.3	b 29.6	b 25.8	c 10.1	a 19.0*	109.6
		63.4	56.6	52.9	55.5	60.9	52.1	341.4

*Each asterick indicates one bird loss.

TABLE 3. Consumption (grams consumed/bird/8-h day) of ground meal (a), 3/16-in diameter pellets (b), and 1/2-in diameter pellets (c) by groups of 5 Starlings in cage tests at Bowling Green, KY.

Series I		Block I			Block II			
Test	Date	Cage 1	Cage 2	Cage 3	Cage 4	Cage 5	Cage 6	Total
B	27 March 80	a 13.0	b 24.7	c 3.0	a 17.0	b 28.3	c 5.3	91.3
	28 March 80	b 26.3	c 4.2*	a 19.3	c 6.5	a 20.3	b 29.9	106.5
	29 March 80	c 7.4	a 22.8*	b 34.7	b 29.0	c 10.3	a 29.0	133.2
		46.7	51.7	57.0	52.5	58.9	64.2	
C	1 April 80	a 27.8	b 31.7	c 4.6	a 20.0	b 29.9	c 4.1*	118.1
	2 April 80	b 29.4	c 1.6	a 22.5	c 7.2	a 23.8	b 31.3	115.8
	3 April 80	c 13.5	a 23.2	b 28.7	b 31.6	c 4.9	a 24.0	125.9
		70.7	56.5	55.8	58.8	58.6	59.4	
D	8 April 80	a 20.5	b 29.6	c 4.6	a 21.5	b 36.9	c 2.9	116.0
	9 April 80	b 27.0	c 5.9	a 22.6	c 5.2*	a 25.3	b 24.8	110.8
	10 April 80	c 9.9	a 28.8	b 33.3	b 29.4	c 8.8	a 24.2	134.4
		57.4	64.3	60.5	56.1	71.0	51.9	1052.0

*Each asterick indicates one bird loss.

were not recorded, this cannot be substantiated. The meaning of the significant interaction term is unknown.

Using techniques described by Federer (1955) the treatment means were adjusted to compensate for the residual treatment effects (Table 4). Analyses of both adjusted and unadjusted means with Duncan's New Multiple Range Test indicates all treatment means were significantly ($P<0.01$) different. Starlings consumed significantly fewer of the 1/2-in pellets than either the ground meal or the 3/16-in pellets. Additionally, ground meal was consumed significantly less than 3/16-in pellets.

During these 3 tests 1 bird escaped and 3 died. All birds were lost during or just after exposure of the 1/2-in diameter pellets. Birds lost during an 8-h test day were assumed alive for 4 h of that day and were thus treated when converting total consumption to grams consumed per bird per 8-h day prior to statistical analysis. All lost birds were replaced as soon as possible after detection. Supplemental feeding with apples appeared to substantially reduce mortality.

Nearly 11 percent mortality occurred during Test E, which featured 20 Starlings per enclosure. Rain, occurring on the second day of the 3-day test, appeared to substantially increase either the consumption of 1/2-in pellets or more probably the non-recovery of spilled 1/2-in pellets on days 2 and 3 (Table 5). No significant ($P>0.05$) increase in consumption of feed sizes among days, however, was detected. Significant ($P<0.05$) differences were detected only among feed sizes (direct treatment effects). The 'F' value for feed size treatment effects (9.48; 2,4 df) and therefore the probability for a significant difference is much less for the enclosure data when compared with the cage data. Duncan's New Multiple Range Test on mean consumption (Table 6) indicates consumption of 1/2-in pellets is significantly ($P<0.05$) less than consumption of 3/16-in pellets. Consumption

TABLE 4. Consumption (grams/bird/8-h day) of feed by groups of 5 Starlings (Series I, Tests B, C, and D) 1980, Bowling Green, KY.

Feed Size	1/2"	Meal	3/16"
Total	109.9	405.6	536.5
$\bar{X} \pm SE$	6.1 ± 0.7	22.5 ± 0.9	29.8 ± 0.8
$\bar{X}$ (adjusted for residual effects)	6.0	22.4	30.0

Means underscored by the same line do not differ significantly ($P<0.05$).

TABLE 5. Consumption (grams/bird/8-h day) of ground meal (a), 3/16-in diameter pellets (b), and 1/2-in diameter pellets (c) by groups of 20 Starlings, Bowling Green, KY.

Series I		Block I			Block II			
Test	Date	Cage 1	Cage 2	Cage 3	Cage 4	Cage 5	Cage 6	Total
E	19 March 80	a 21.6	b 25.1	c 7.4(3)	a 23.9(2)	b 27.0	c 12.8(4)	63.7
	20 March 80	b 26.9	c 28.3(2)	a 20.9	c 25.2(1)	a 26.6	b 25.9(1)	80.7
	21 March 80	c 17.0	a 23.6	b 26.6	b 32.0	c 26.8	a 24.8	83.6
		65.5	77.0	54.9	80.1	80.4	67.5	228.0

$\bar{X} \pm SE$ a = 23.6 ± 0.9

b = 27.9 ± 1.0

c = 19.6 ± 3.5

(#) Number indicates bird losses.

TABLE 6. Consumption (grams/bird/8-h day) of ground meal, 3/16-in pellets, and 1/2-in pellets by groups of 20 Starlings (Series I, Test E), Bowling Green, KY.

Feed Size	1/2"	Meal	3/16"
Total	116.5	141.4	167.5
$\bar{X} \pm SE$	20.47 ± 3.47	23.57 ± 0.85	27.92 ± 1.04

Means underscored by the same line do not differ significantly (P<0.05).

of ground meal did not differ significantly ($P>0.05$) from either 3/16-in or 1/2-in pellets.

Tests comparing ground meal, 3/16-in and 1/2-in pellets indicate Starlings consume significantly ($P<0.05$) less 1/2-in pellets than 3/16-in pellets. Ground meal was consumed less than 3/16-in pellets but more than 1/2-in pellets. Starlings were generally unable to break apart the 1/2-in pellets nor were they able to survive only on 1/2-in pellets unless supplemental feed was provided. On the other hand, excessive moisture (rain) resulted in pellet disintegration and increased consumption of 1/2-in pellets by Starlings.

Series II: No-choice preference tests; 3/16, 1/4 and 3/8-in pellets.

The next series of cage tests compared consumption among 3/16, 1/4 and 3/8-in diameter pellets in a 3 x 3 latin square design. Consumption data for Tests A, B, and C are presented in Table 7. Analysis of Tests A and B yielded significant ($P<0.05$) differences between latin squares. Highly significant ($P<0.01$) differences in consumption were also detected among pellet sizes. Most of the variability among pellet sizes can be accounted for by the reduced consumption of the 3/8-in pellets in Test B. When analyzed individually, Test A failed to yield any significant ($P>0.05$) differences among pellet sizes whereas Test B did. This difference between tests may have been due to a learning process within the larger group (see below).

Because of a lack of naive birds, an additional 3-day test (Test C) was conducted with the same 3 Starlings per cage as were used in the above test. Consumption of 3/8-in pellets increased markedly from Test B to Test C. Analysis of Test B yielded no significant differences among cages, days nor treatments. Mean consumption data for Tests B and C are compared in Table 8. These data indicate Starlings can learn to consume 3/8-in diameter pellets.

TABLE 7. Consumption (grams/bird/8-h day) of 3/16-in (a), 1/4-in (b), and 3/8-in (c) diameter pellets by groups of 5 and 3 Starlings in cage tests at Bowling Green, KY.

Series II					
Test	Date	Cage 1	Cage 2	Cage 3	Total
(5 Starlings/cage)					
A	31 March 81	a 24.8	b 16.7	c 8.0	49.5
	1 April 81	b 22.6	c 12.4	a 18.7	53.7
	2 April 81	c 15.2	a 24.4	b 23.0	62.6
		62.6	53.5	49.7	165.8
(3 Starlings/cage)					
B	15 April 81	a 25.7	c 10.7	b 25.5	61.9
	16 April 81	b 28.0	a 27.7	c 14.0	69.7
	17 April 81	c 12.0	b 25.0	a 27.8	64.8
		65.7	67.3	63.4	196.4
(3 Starlings/cage)					
C	20 April 81	a 23.0	b 23.7	c 22.7	69.4
	21 April 81	b 29.2	c 25.3	a 31.2	85.7
	22 April 81	c 27.0	a 25.7	b 27.3	80.0
		79.2	74.7	81.2	235.1

TABLE 8. Mean consumption of 3/16-in, 1/4-in, and 3/8-in pellets by naive and previously exposed Starlings in groups of 3, 1981, Bowling Green, KY.

	Consumption $\overline{X}\pm SE$ (grams/bird/8-h day)		
	3/16"	1/4"	3/8"
Naive (Test B)	27.1±0.7	26.2±0.9	12.2±1.0
Previously exposed (Test C)	26.6±2.4	26.7±1.6	25.0±1.2

Means underscored by the same line do not differ significantly (P<0.01).

Supplemental feed (apples) was offered during these initial 3 test periods with 3/8-in pellets. However, when observations of captive Starlings feeding on the 3/8-in pellets revealed that Starlings could successfully swallow whole 3/8-in pellets, supplemental feeding was stopped.

Nearly all Starlings would initially remove the 3/8-in pellets from the feeder and scatter them about the cage, and eventually a few individuals would manage to orient a pellet lengthwise in their beaks and would thus be able to swallow the pellet. After ingestion of a pellet the individual bird would have a noticeably enlarged throat area due to the presence of the large pellet and would become very inactive. Swallowing this size pellet appeared to be difficult and uncomfortable for Starlings. Based on these observations further tests of 3/8-in pellets were warranted because it appeared that Starlings would not consume many 3/8-in pellets in normal feedlot situations.

Therefore 8 additional 3-day cage tests with 3/16, 1/4 and 3/8-in diameter pellets were conducted between 10 November 1981 and 17 January 1982. Five tests (D-H) involved 1 Starling per cage and 3 tests (I, J, and K) involved 5 Starlings per cage. Analysis of consumption data for all tests with 1 Starling per cage (Table 9) yielded highly significant ($P<0.01$) differences in consumption among the three pellet sizes (Table 10). Further analysis indicated that consumption of the 1/4 in and the 3/16-in pellets was not significantly ($P>0.05$) different but that consumption of the 3/8-in pellet was significantly ($P<0.01$) less than that of the other 2 sizes. Additionally, significant ($P<0.05$) differences were noted among tests and among days within tests. Consumption of pelleted feeds on one day, however, seems to have had no predictable effect on consumption the next day. Differences in consumption among tests may have been due in part to the ambient temperature.

TABLE 9. Consumption (grams/bird/8-h day) of 3/16-in (a), 1/4-in (b), and 3/8-in (c) diameter pellets by individual male Starlings, Bowling Green, KY.

Series II Test	Date	Cage 1	Cage 2	Cage 3	Total
D	10 Nov 81	a 29.0	c 14.0	b 18.5	61.5
	11 Nov 81	b 20.0	a 22.0	c 4.0	46.0
	12 Nov 81	c 8.5	b 23.0	a 20.5	52.0
		57.5	59.0	43.0	159.5
E	10 Nov 81	a 27.0	b 24.0	c 11.0	62.0
	11 Nov 81	c 9.5	a 27.0	b 20.0	56.5
	12 Nov 81	b 2.0	c 4.5	a 2.0*	8.5
		38.5	55.5	33.0	127.0
F	10 Nov 81	c 3.5	a 35.0	b 30.0	68.5
	11 Nov 81	a 13.0	b 24.0	c 13.5	50.5
	12 Nov 81	b 23.0	c 20.0	a 36.0	79.0
		39.5	79.0	79.5	198.0
G	10 Nov 81	b 26.5	c 15.5	a 31.0	73.0
	11 Nov 81	a 24.0	b 26.0	c 32.0	82.0
	12 Nov 81	c 1.0*	a 5.0	b 19.0	35.0
		51.5	56.5	82.0	190.0
H	10 Nov 81	c 0.5*	b 41.0	a 31.5	73.0
	11 Nov 81	a 32.0	c 0.5	b 27.0	59.5
		b 32.5	a 40.5	c 18.5	91.5
		65.0	82.0	77.0	224.0

*Indicates one bird loss.

TABLE 10. Mean consumption of 3/16-in, 1/4-in, and 3/8-in pellets by individual Starlings and Starlings in groups of 5, 1981-1982, Bowling Green, KY.

Starlings/ Cage	Consumption (grams/bird/8-h day)		
	3/16"	1/4"	3/8"
1	25.0 ± 2.86	23.8 ± 2.17	10.4 ± 2.27
5	23.0 ± 1.57	21.5 ± 2.55	22.8 ± 2.35

Means underscored by the same line do not differ significantly ($P<0.01$).

The mean temperature varied from $8^{o}C$ in November to $-17^{o}C$ in January. The metabolic rate and therefore the energy required in the form of foodstuffs has been shown to fluctuate with temperature (Kelty and Lustick 1977).

Analysis of consumption data for Tests I, J, and K with 5 Starlings per cage (Table 11) revealed no significant ($P>0.05$) differences in consumption among the 3 pellet sizes (Table 10). Comparisons of consumption by Starlings among tests, cages within tests, and days within tests all yielded significant ($P<0.05$) differences. These data seem to indicate that Starlings in groups can rapidly learn to ingest 3/8-in diameter pellets, probably by simple observation of those individuals that develop the proper technique by trial and error. The highly significant ($P<0.01$) difference among cages is unexpected since variability in consumption among groups of 5 birds was anticipated to be less than the differences among individual birds (1 bird/cage) which were insignificant. All tests with 5 birds per cage were conducted under similar climatic conditions, therefore differences among blocks cannot be attributed to weather related energetic requirements.

Tests comparing 3/16, 1/4 and 3/8-in diameter pellets indicate that individual Starlings consume lesser amounts of 3/8-in pellets than either 3/16 or 1/4-in pellets. However, Starlings in groups of 5 and Starlings previously exposed to 3/8-in pellets can learn to consume these pellets in amounts similar to the smaller diameter pellets.

Series III: 2-choice preference tests; 3/8 vs 3/16-in pellets or meal.

The final series of cage tests compared consumption of 3/8-in pellets with consumption of ground meal and 3/16-in pellets, respectively, in 2-choice preference tests. Data from 24, 1-day tests conducted between

TABLE 11. Consumption (grams/bird/8-h day) of 3/16-in (a), 1/4-in (b), and 3/8-in (c) diameter pellets by groups of 5 Starlings, Bowling Green, KY.

Series II Test	Date	Cage 1	Cage 2	Cage 3	Total
I (females)	15 Jan 82	c 17.2	b 19.4	a 25.0	61.6
	16 Jan 82	b 9.4	a 23.4	c 22.6	55.4
	17 Jan 82	a 21.1	c 31.8	b 25.0	77.9
		47.7	74.6	72.6	194.9
J (males)	15 Jan 82	c 10.4	a 22.2	b 28.4	61.0
	16 Jan 82	a 14.0*	b 23.6	c 26.2	63.8
	17 Jan 82	b 14.0	c 21.4	a 27.8	63.2
		38.4	67.2	82.4	188.0
K (males)	15 Jan 82	c 18.7	b 29.8	a 30.8	79.3
	16 Jan 82	a 22.2	c 32.8	b 30.0	85.0
	17 Jan 82	b 14.0	a 20.9	c 24.1	59.0
		54.9	83.5	84.9	223.3

*Indicates one bird loss.

13 November 1981 and 30 March 1982, are summarized in Table 12. Four 1-day tests comparing consumption of 3/16-in pellets with 3/8-in pellets using 1 Starling per cage indicated nearly total preference for the 3/16-in pellet. Twenty 1-day tests comparing ground meal with 3/8-in pellets resulted in greater variability in Starling preferences. Results from 9 tests with 1 Starling per cage revealed a marked preference ($P<0.001$) for ground meal. In groups of 5, however, Starlings consumed greater amounts of 3/8-in pellets than ground meal, although no significant differences in consumption were detected. These data indicate that in groups Starlings can consume 3/8-in pellets in quantities similar to quantities of ground meal.

Cage Test Summary

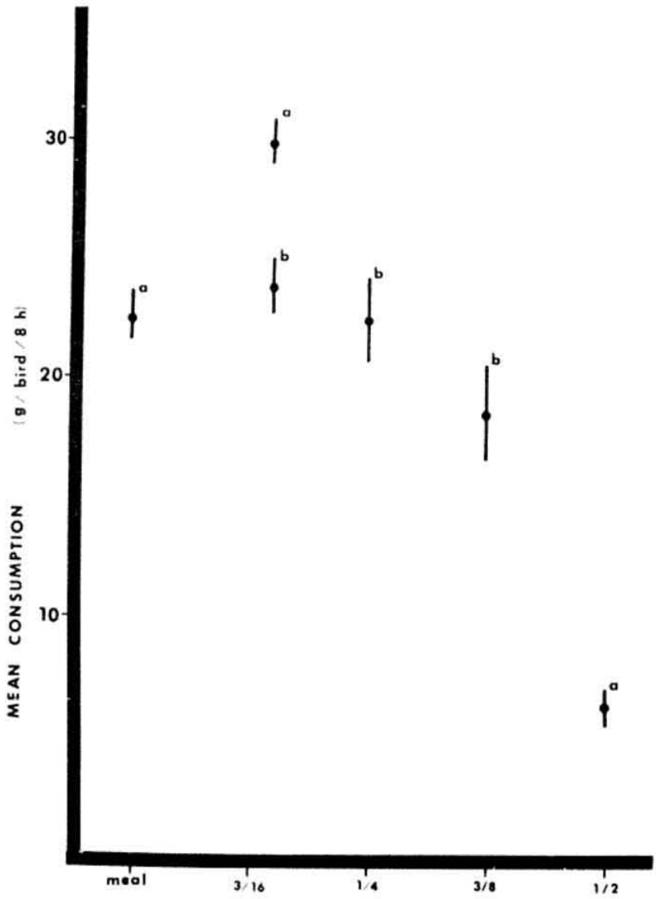
In no-choice preference tests captive Starlings consumed significantly less ground meal, 3/8-in and 1/2-in pellets than 3/16-in and 1/4-in pellets. However, consumption of 1/2-in pellets was significantly less than consumption of either ground meal or 3/8-in pellets. Consumption of the latter 2 feed sizes were similar among Starlings in groups of 5 but consumption of 3/8-in pellets by individual Starlings was significantly less. This phenomenon indicates a learning process is required for Starlings to consume 3/8-in diameter pellets. Mean consumption of all feed sizes by Starlings in groups of 5 is summarized in Figure 4.

Two-choice preference tests support the above conclusions. Starlings exhibited a nearly total preference for 3/16-in pellets over 3/8-in pellets. Additionally, individual Starlings had a marked preference for ground meal over 3/8-in pellets while Starlings in groups of 5 exhibited no significant preference between ground meal and 3/8-in pellets.

TABLE 12. Mean consumption (grams/bird/8-h day) of meal, 3/16 and 3/8-in pellets by Starlings in 24, 2-choice preference tests, 1981-1982, Bowling Green, KY.

Starlings/ cage	N	3/16"	3/8"	Meal	t	P
1	4	25.0±1.41	0.25±0.25	———	18.82	<.001
1	9	———	0.1±0.11	24.78±2.83	8.62	<.001
5	11	———	10.81±2.88	8.45±1.97	0.55	>1.0

Figure 4. Mean consumption (g/bird/8 h day) of 5 livestock feed sizes by Starlings in groups of 5 during cage tests, 1980-1982, Bowling Green, KY.



FEED SIZE

a,b – Means with common letter are from the same test series.

Field Tests

Roosts

Major blackbird-Starling roost sites were located within the city limits of Bowling Green and Glasgow (Figs. 2 and 3). Many of the Starlings that foraged at the livestock feeding area-test sites during this study probably roosted at these sites. This is indicated by the recovery of 2 tags (1 back and 1 wing) that had been placed on birds at the WKU Farm from the Bowling Green roost on 26 March 1982.

Bird population dynamics at these 2 roosts were considerably different. The Bowling Green roost increased in numbers during the study period from less than 5,000 birds on 13 December, to 10,000 birds on 6 January, to 200,000 on 20 January, and increasing thereafter until reaching a maximum number of nearly 1 million birds on 5 March. The Glasgow roost, on the other hand, declined in bird numbers during the study period with a sharp decrease towards the latter part of the study, due in part to PA-14 treatments of this roost on 31 January and 5 February. Bird numbers at this roost site rose from nearly 1 million on 22 January to nearly 2 million on 1 February (morning after the first spray), then declined precipitously to 830,000 on 2 February, to 430,000 on 5 February (morning after second spray night), and to 110,000 on 11 February. Species composition at the Glasgow roost on 5 February was 40% Grackles, 27% Starlings, 23% Red-winged Blackbirds, and 10% Cowbirds.

One additional roost of greater than 100,000 birds was reported north of Russellville in Logan County (Head, Personal Communication). I was unable to locate this roost, but due to its distance from test sites it probably contained few of the Starlings that frequented the test sites with the possible exception of the Logan County site.

2-Choice preference test

Two experimental feed troughs were placed within 10 m of each other at the Logan County livestock feeding location. The weight of pellets exposed was increased from 0.5 kg initially to 5.0 kg at the termination of this test. Nearly twice as many kilograms of 3/16-in pellets (15 kg) as 3/8-in pellets (8.5 kg) were consumed during this test (Table 13). Nevertheless, a t-test analysis indicated no significant ($P>0.10$) preference for either pellet size by Starlings, probably because of the great variability in consumption within each pellet size (Table 13). This 2-choice preference test was terminated on 17 January 1982 and the test site was thereafter included in the following no-choice test.

No-Choice preference test

Experimental troughs were first placed at the south Warren County feeding locations in early December and at the north Warren County and Barren County sites in early January. The first test period began 11 January 1982 at all feeding locations with the exception of Logan County where the initial test period began on 19 January 1982. Consumption data from all feeding locations (Table 14) were computer analyzed by Statistical Analysis Service, General Linear Models, Type IV, Analysis of Variance. These data indicate Starlings consumed significantly ($P<0.01$) more 3/16-in pellets than 3/8-in pellets (200 kg vs 127 kg). Starlings often removed 3/8-in pellets from the trough and dropped them on the ground next to the trough, with up to 1.52 kg of 3/8-in pellets recovered from the ground on 1 day at 1 site. However, all pellets removed from a trough were considered lost to Starlings. If the total amount of 3/8-in pellets remaining (both in trough and on the ground) were subjected to analysis, differences between the 2 pellet sizes would be even greater. The above ANOVA also

TABLE 13. Consumption (kilograms/24-h day) of 3/16-in and 3/8-in diameter pellets by free-ranging Starlings at a Logan County livestock feeding area.

Date		3/16" Pellets	3/8" Pellets
19 Dec 81		0.01	0.00
24 Dec 81		.00	.00
25 Dec 81		.01	.00
27 Dec 81		.04	.07
28 Dec 81		.07	.02
29 Dec 81		.05	16
30 Dec 81		.02	.24
5 Jan 82		.01	.15
6 Jan 82		.00	.00
7 Jan 82		.00	.00
8 Jan 82		.25	.25
10 Jan 82		.17	.17
11 Jan 82		.20	.16
12 Jan 82		.10	.18
13 Jan 82		.95	.31
14 Jan 82		1.00	.98
15 Jan 82		3.64	.73
16 Jan 82		3.72	.97
17 Jan 82		4.85	4.15
	Total	15.09	8.54
	$\bar{X} \pm SE$	0.79 ± 0.34	0.45 ± 0.22
$t = 1.66$		$df = 18$	$P > 0.10$

TABLE 14. Consumption (kilograms/24-h day) of 3/16 in (S) and 3/8 in (L) diameter pellets by free-ranging Starlings when presented a single choice.

Date	North Warren County Site 1	North Warren County Site 2	Barren County Site 3	Barren County Site 4	South Warren County Site 5	South Warren County Site 6	Logan County Site 7	Sub totals	Totals
11 Jan 82	S 0.10	L 0.00	[illegible] 0.00	L 0.00	[illegible] 0.00	L 0.01		0.13	[illegible]
12 Jan 82	L 0.18	S 0.03	L 0.04	S 2.50*	L 0.12	S 0.25		[illegible]	
13 Jan 82	S 0.12	L 0.00	[illegible] 0.00	L 1.[illegible]	[illegible] 0.54	L 0.01		2.04	[illegible]
14 Jan 82	L 0.72	S 0.06	L 0.00	S 4.[illegible]	[illegible]	S 4.00*		10.41	
16 Jan 82	L 1.54	[illegible] 0.07	S 0.40	[illegible]	[illegible]	[illegible]		14.12	[illegible]
17 Jan 82	S 4.73	L 0.05	L 0.73	S 9.[illegible]	[illegible]	[illegible]		23.25	
19 Jan 82	S 0.78	L 0.03	L 0.16	[illegible]	[illegible] 0.62	[illegible]	S 4.[illegible]	10.35	[illegible]
20 Jan 82	L 0.09	S 0.00	S 1.06	[illegible]	[illegible] 0.00	[illegible] 0.47	L 0.78	[illegible]	
23 Jan 82	S 1.64	L [illegible]	L 2.59	[illegible]	[illegible] 0.11	[illegible]*	[illegible]	[illegible]	[illegible]
24 Jan 82	L 0.06	S 1.14	S 3.00	[illegible]*	[illegible]	L [illegible]	[illegible]	[illegible]	
25 Jan 82	S [illegible].97	L 1.36	L 7.62	L [illegible]*	[illegible]	[illegible]	L [illegible]	[illegible]	[illegible]
27 Jan 82	L 1.16	S 1.45	S 7.71	[illegible]	[illegible]	L [illegible]	[illegible]	[illegible]	
29 Jan 82	S 1.22	L 3.27	S 5.00*	L [illegible]	[illegible]	[illegible]	[illegible] 4.90	26.06	[illegible]
30 Jan 82	L [illegible]	S [illegible].45	L 5.04	S 4.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1 Feb 82					[illegible]	[illegible]*	[illegible]	[illegible]	[illegible]
2 Feb 82					[illegible]	[illegible]	[illegible]	[illegible]	
4 Feb 82	L 0.35	L 1.37			[illegible]*	[illegible]*		[illegible]	[illegible]
5 Feb 82	S 3.00*	[illegible] 1.00*			[illegible]*	[illegible]		[illegible]	
7/8 Feb 82	L 0.00	L 0.83			[illegible]*	[illegible]	[illegible]	[illegible]	[illegible]
8/9 Feb 82	S 1.85	S 1.00*			[illegible]	[illegible]	[illegible]	[illegible]	
10/11 Feb 82	L 1.34	S 2.05			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/12 Feb 82	S 0.63	L 1.20			[illegible]	[illegible]	[illegible]	[illegible]	
Total	27.51	24.44	33.34	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
$\bar{x}\pm SE$	1.4±0.3	1.[illegible]±0.3	2.4±0.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

*Indicates no pellets remaining after 24 h.

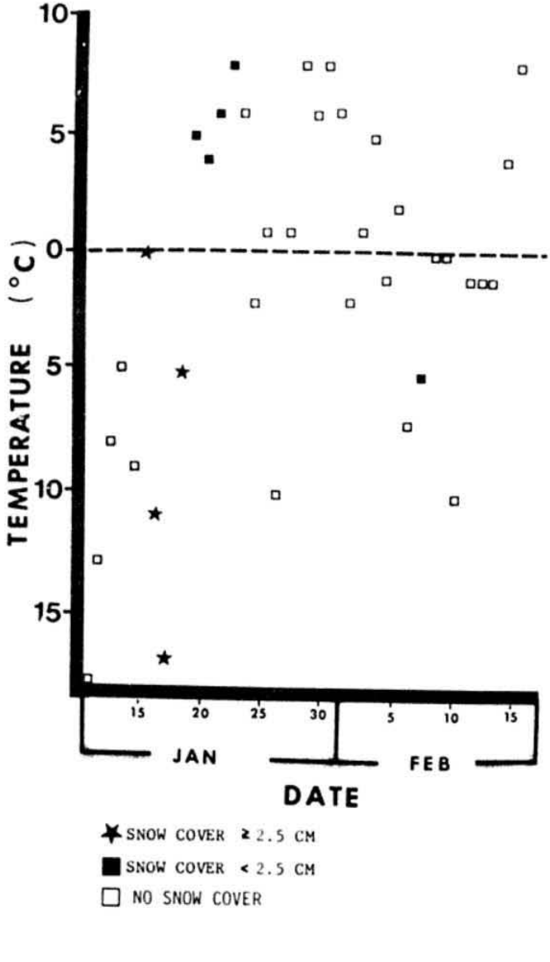
indicated highly significant ($P<0.01$) differences among test sites, among periods and attributed to the period x site interaction.

Differences in mean daily consumption among test sites varied from highs of 4.81 kg and 3.60 kg at Sites 4 and 6, respectively, to lows of 1.22 kg and 1.37 kg at the 2 north Warren County sites. Mean (2-day) consumption among periods varied from 0.45 kg on 11-12 January to 10.62 kg on 26-27 January.

Mean daily temperatures (Figure 5) were subjected to Spearman's Rank Correlation Analysis versus mean daily consumption yielding a correlation coefficient of -0.03. This correlation coefficient indicates no significant ($P>0.01$) correlation between temperature and pellet consumption and thus fails to substantiate previous associations found between Starling numbers in feedlots and severe winter weather (Dunnet 1956, Bailey 1966, White 1980, Glahn and Otis 1982). However, these data are biased due to differences in the pellet size exposed, limiting the amounts of pellets exposed, and inconsistent exposure of pellets at all sites on each day.

The number of Starlings observed daily at each feeding location, except Logan County, are listed in Table 15. Total daily pellet consumption data at all feeding locations, except Logan County, regardless of pellet size, and total daily Starling numbers from all contributing locations, were subjected to a Spearman's Rank Correlation Analysis. This analysis yielded a correlation coefficient of 0.33, and thus indicated no significant ($P>0.1$) relationship between the number of birds observed and pellet consumption. The analysis, however, is based on a single observation per day which cannot adequately monitor changes in bird populations. The lack of relationship between observed bird numbers and consumption was therefore not unexpected. A similar correlation analysis was used to compare the the mean number of birds observed at a site with the mean daily consumption

Figure 5. Mean daily temperature and snow cover, Bowling Green, Kentucky (10 January - 15 February 1982).



TEMPERATURE (°C)
10
5
0
5
10
15
15
20
25
30
5
10
15
JAN
FEB
DATE
SNOW COVER ≥ 2.5 CM
SNOW COVER < 2.5 CM
NO SNOW COVER

TABLE 15. Number of Starlings observed at livestock feeding areas in Southcentral Kentucky, 1982.

Date		North Warren County		Barren County		South Warren County
		Site 1	Site 2	Site 1	Site 2	WKU-Farm transect
Jan	4					0
	6					30
	8					17
	11	200	25	--	2	20
	12	200	10	--	100	--
	13	100	5	50	100	--
	14	300	25	50	70	80
	15	200	50	10	50	--
	16	200	20	0	100	145
	17	80	20	10	150	75
	18	--	--	--	--	50
	19	100	2	5	100	5
	20	25	50	350	50	0
	21	60	0	5	10	--
	22	--	--	--	--	0
	23	50	30	10	10	0
	24	100	30	0	100	40
	25	10	100	100	80	85
	26	0	25	50	15	70
	27	110	250	400	200	220
	28	50	5	300	100	70
	29	150	50	100	350	150
	30	--	--	100	200	0
	31	--	--	--	--	--
Feb	1	80	50	10	20	120
	2	10	0	100	200	260
	3	--	--	0	200	150
	4	30	5	0	50	210
	5	50	80	80	120	510
	6	50	50	50	100	250
	7	--	--	--	--	--
	8	30	80	--	--	0
	9					
	10	30	5	--	--	300
	11	100	50	--	--	200
	12	20	150	--	--	200
	16			--	--	200
	$\bar{X}$	93	45	81	103	115

at that site for the entire study. This analysis yielded a correlation coefficient of 0.49, again indicating no significant ($P>0.01$) relationship between observed bird numbers and pellet consumption.

Sixteen film-consumption pair days were obtained from 3 test sites; Sites 4, 6, and 7. Film data obtained from Site 5 were excluded from analysis due to an intervalometer malfunction resulting in film exposure of greater than 1 frame per 10 seconds. Starlings accounted for about 99% of all birds observed on film. The only other species to actively use these experimental feed troughs was the House Sparrow (Passer domesticus, Linnaeus), with significant numbers occurring only at the Logan County site. House Sparrows were not counted during film analysis due to their likely negligible consumption of pellets and relatively few appearing on film. The number of Starlings on the edge of the trough and in the trough were enumerated separately for each frame. Starlings were divided nearly equally between the edge (60,410) and inside (63,652).

Limited data on individually tagged Starlings were obtained at both south Warren County sites. Nine individually tagged Starlings made 55 visits to these troughs during 8 days of film monitoring. Unlike the data on total bird numbers, tagged birds spent more time on the edge of the trough (65%) than inside feeding (35%). No estimate of the time an individual bird stayed at the trough was obtained since approximately 80% of all tags observed were from Site 5 which had the malfunctioning intervalometer.

Regression analysis (Y intercept through the origin) of daily, film-bird numbers, both total and every sixth frame, versus their respective pellet consumption yielded equations with slope estimates of 0.512 and 3.055, respectively. These equations predict that for every 1000 film-bird-minutes of Starling activity (i.e.,every sixth frame) 3.055 kg of

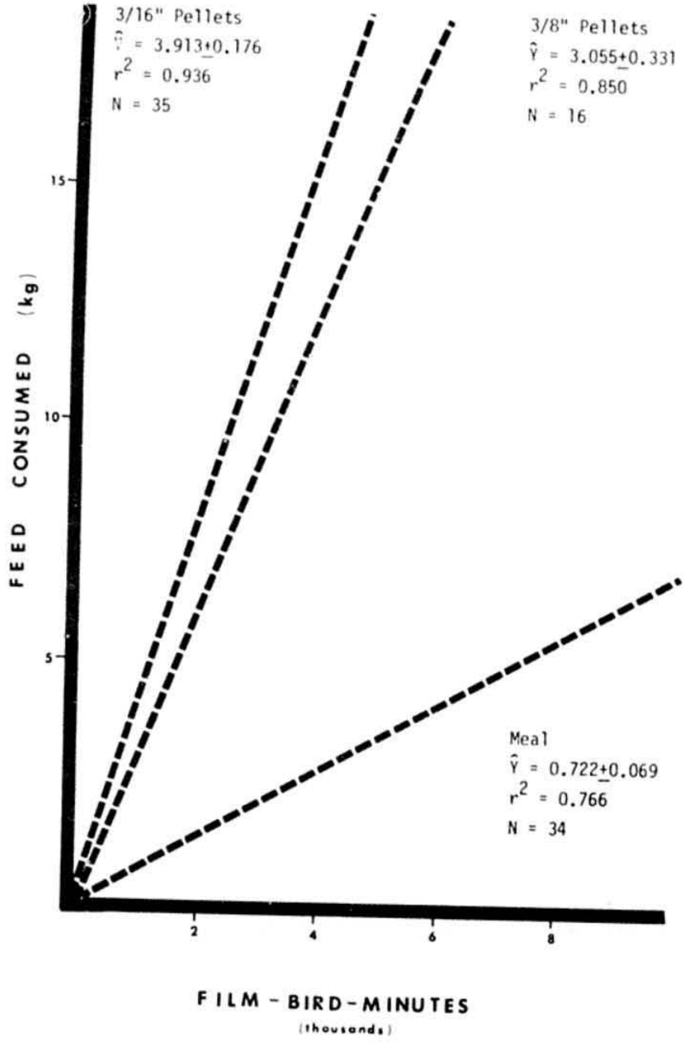
3/8-in pellets are consumed. Based on total film-birds (i.e., every frame) a predicted 0.512 kg of 3/8-in pellets are consumed per 1000 film-bird-frames of Starling activity. Projection of consumption per 1000 film-bird-frames of Starling activity to consumption per 1000 film-bird-minutes of Starling activity (6 x 0.512) yields a value of 3.072 kg. The close approximation of these 2 consumption figures (3.055 and 3.072) indicates that a time lapse film sample of 1 frame per minute is adequate to monitor Starling populations at feed troughs.

The above data can be compared with film-bird consumption data on 3/16-in pellets and ground meal collected by and presented herein courtesy of James F. Glahn and his associates at the Kentucky Research Station, U.S. Fish and Wildlife Service, Bowling Green, KY. Regression analysis of these feed sizes results in equations that predict 3.913 kg of 3/16-in pellets or 0.722 kg of ground meal are consumed per 1000 film-bird-minutes of Starling activity and 0.678 kg of 3/16-in pellets and 0.121 kg of ground meal are consumed per 1000 film-bird-frames of Starling activity. A Student's t-test analysis between each pair of regression slopes indicated that the consumption rate was significantly ($P<0.05$) different for all feed sizes (Figures 6 and 7).

Field Test Summary

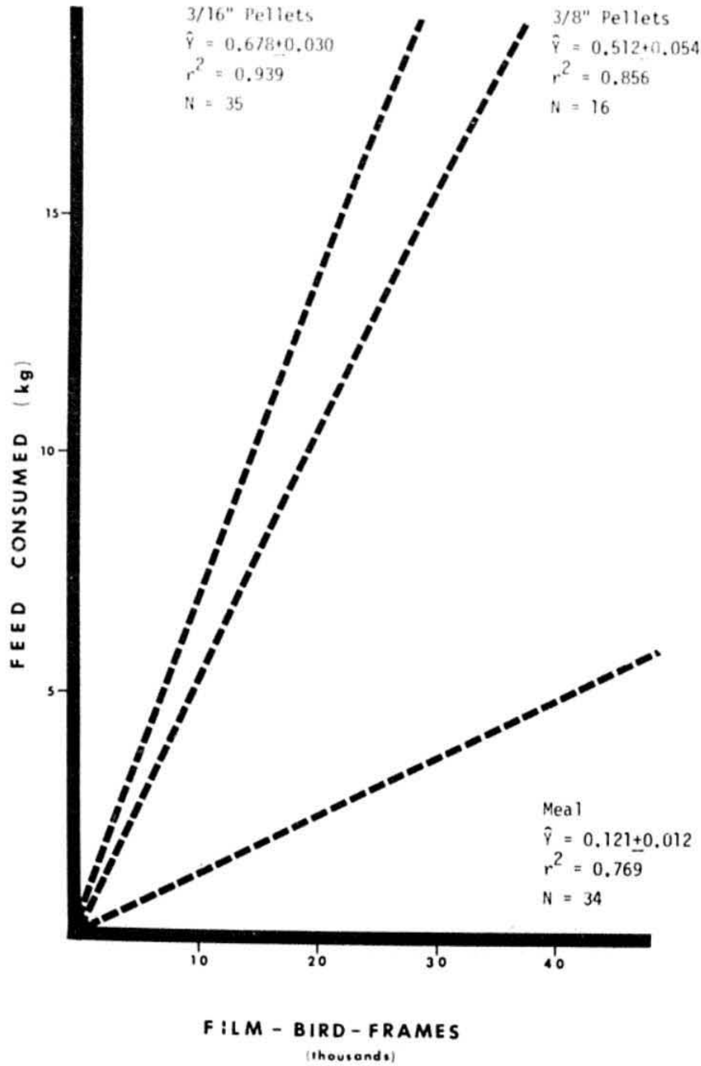
These field tests indicate that 3/8-in pellets are consumed in significantly ($P<0.01$) lesser amounts than 3/16-in pellets by free-ranging, depredating Starlings during the winter. Analysis of data obtained by time lapse film indicates 1000 film-bird-minutes of Starling activity results in a consumption rate of 3.9 kg of 3/16-in pellets and 3.0 kg of 3/8-in pellets. However, the consumption rate of ground meal at only 0.71 kg per 1000 film-bird-minutes of Starling activity is dramatically less than either pelleted feed.

Figure 6. Feed consumption versus film-bird-minutes of Starling activity obtained from time lapse film.



3/16" Pellets
$\hat{Y} = 3.913 \pm 0.176$
$r^2 = 0.936$
N = 35
3/8" Pellets
$\hat{Y} = 3.055 \pm 0.331$
$r^2 = 0.850$
N = 16
Meal
$\hat{Y} = 0.722 \pm 0.069$
$r^2 = 0.766$
N = 34
FEED CONSUMED (kg)
15
10
5
2
4
6
8
FILM - BIRD - MINUTES
(thousands)

Figure 7. Feed consumption versus film-bird-frames of Starling activity obtained from time lapse film.


3/16" Pellets
Ŷ = 0.678+0.030
r² = 0.939
N = 35
3/8" Pellets
Ŷ = 0.512+0.054
r² = 0.856
N = 16
Meal
Ŷ = 0.121±0.012
r² = 0.769
N = 34
FEED CONSUMED (kg)
15
10
5
10
20
30
40
FILM - BIRD - FRAMES
(thousands)

General Discussion

The objective of this study, to determine the minimum livestock feed size that Starlings are unable to consume in significant quantities yet is still acceptable in size to livestock, was only partially met. Starlings were unable to consume significant quantities of 1/2-in diameter pelleted livestock feeds. However, 1/2-in pellets must be protected from excessive moisture and must be compressed to a hardness of 59 Shore D (LaVoie et al. 1982) in order to withstand the pecking force of Starlings.

Individual Starlings did not consume significant amounts of 3/8-in pellets but Starlings in groups learned to ingest this pellet size in amounts not significantly ($P>0.05$) different from 3/16-in pellets. Nevertheless, analysis of time lapse film data indicates Starlings can consume 3/16-in pellets at a significant ($P<0.05$) faster rate than 3/8-in pellets.

Cage tests indicate consumption of ground meal, while similar to consumption of 3/8-in pellets, was significantly less than 3/16-in pellets but greater than 1/2-in pellets. However, data from time lapse film revealed Starlings consume 3/16-in pellets 5 times faster, and 3/8-in pellets 4 times faster than ground meal. This discrepancy may be attributed to the small particle size of ground meal that required a Starling to spend a greater amount of time to consume amounts equal to the weight of a few pellets.

Ground meal is widely used as a livestock feed, and 3/8-in pellets have been shown to be beneficial to growing swine (Braude and Rowell 1966). On the other hand, acceptability of 1/2-in diameter pelleted feeds by smaller livestock (such as young pigs) may be a limiting factor to their widespread use.

Based on this study, 3/8-in and 1/2-in diameter pellets (when protected from excessive moisture) and ground meal are effective in reducing livestock feed consumption by depredating Starlings. The most effective feed size tested was 1/2-in diameter pellets. However, the minimum feed size that Starlings are unable to consume in significant amounts may be between 3/8 and 1/2-in in diameter. Due to anticipated acceptance problems by smaller livestock, use of 1/2-in pellets will probably be restricted to larger livestock. On the other hand, ground meal may be fed to smaller livestock with less losses to Starlings than if 3/16-in pellets are fed.

SUMMARY

Captive Starlings were offered 5 sizes of 15%-17% protein swine feeds to determine differences in consumption. Consumption of 3/16-in and 1/4-in diameter pelleted feeds were greatest with significantly less consumption of ground meal, 3/8-in and 1/2-in diameter pellets. Starlings consumed significantly less 1/2-in diameter pellets than either ground meal or 3/8-in diameter pellets and were unable to survive without supplemental feed. Field tests with free ranging Starlings, conducted to determine differences in consumption between 3/16-in pellets and 3/8-in pellets, resulted in consumption of significantly fewer 3/8-in pellets. Use of ground meal and pellets 3/8 and 1/2 inches in diameter was found to be more effective in reducing livestock feed losses to depredating Starlings than use of 3/16 and 1/4-in pellets.

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